URBAN MOSQUITO MANAGEMENT IN BRISBANE – PAST, PRESENT AND FUTURE

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Abstract
The history of the management of pest mosquito populations in the city of Brisbane and adjacent areas is described. The evolution of techniques, over almost a century, from the earliest attempts at larval control by manual oil application to water bodies, through to modern, highly targeted, computer controlled, aerial application of highly specific chemicals is outlined. The role of mosquito specialist Dr Elizabeth Marks in these events is highlighted.

Introduction
Brisbane is a subtropical city straddling the low-lying estuary of the Brisbane River, with its adjacent mangroves and saltmarshes. This situation poses many potential problems for mosquito control and the way these have been tackled has evolved over the years. For the early years this summary draws heavily on an address in 1960 to the Entomological Society of Queensland by J.D. Mabbett, then Chief Health Officer of Brisbane City Council (Mabbet 1960).

Events prior to the 2nd World War
In 1912, the Queensland Commissioner of Public Health, Dr J.S.C. Elkington, arranged a preliminary mosquito survey in Brisbane and suburbs under Lance Cooling. This led to the first mosquito regulations in the same year, but by 1921 the only organised activity was oiling of gully traps in parts of Brisbane, South Brisbane, Toombul and Toowong.

In 1921, the 'Mosquito Prevention and Destruction Regulations' were introduced to control *Aedes aegypti* (L.). Cooling was urging local authorities to provide permanent means of foul-water drainage to control *Culex fatigans* Wiedemann [now *Culex quinquefasciatus* Say]. This species was the known vector of filariasis, common in Brisbane at the time.

When Greater Brisbane was established as a single Council in 1925, the Medical Officer, Dr Tilling, arranged quicker coverage of gully traps by providing a horse and buggy. In 1928, the Council appointed Dr Ronald Hamlyn-Harris as City Entomologist, in response to concern about mosquito control. Staff comprised a supervisor, four mosquito locators and four sprayers. In 1932, the section was using three tricycles (Fig. 1) to speed up treatment of gully traps. In 1934, three motorcycle units were introduced. The program targeted mosquito larvae, using various oils and kerosene mixtures as larvicides.

Figs 1-2. (1) Bicycle-carried oil equipment being used against mosquito larvae, Brisbane City Council, date unknown. (2) The Brisbane City Council mosquito control team, 1959.

The new era following the 2nd World War

The impact of the Second World War on interest in mosquitoes in Australia was very significant, due to concerns about malaria in the South Pacific and Southeast Asia, and the possibility of returning soldiers bringing malaria parasites home. There was also a serious epidemic of malaria in Cairns in 1942. After the war, many ex-servicemen with war-time experience in pest control were employed by Brisbane City Council. Many of these men would have been trained during the war in courses run at the University of Queensland by Mr F.A. Perkins of the UQ Entomology Department, with Elizabeth (Pat) Marks as their instructor. In the three years following the war, a complete re-survey of mosquitoes in Brisbane was undertaken, with particular attention paid to *Anopheles* because of the malaria issue. Larvicides in use after the war included DDT and malariol.

In 1949, Brisbane was divided into ten zones, with men and motorcycle units designated to each. Gully traps were also covered in a separate control schedule. In 1950, Council purchased its first truck-mounted, thermal-fogging machine for adult mosquito control, and by 1960 there were four of these units (Figs 2, 3). However, control of mosquito larvae was still the main task of the program. One product used successfully for this was 'Larvabane', based on benzene hexachloride, claimed to be 'very toxic to mosquito life but safe to beneficial fish life'. During the 1950s, 'house to house inspections and remedial action' led to the virtual elimination of *Ae. aegypti* and the claim that 'dengue has been beaten'. (There had been an outbreak of dengue in Brisbane in 1905 that was reported to have incapacitated one third of the work force and caused many fatalities, and there were other outbreaks up to and including the 1940s).

In the 1950s, *Culex annulirostris* Skuse began to take the place of *Cx. fatigans* as drainage and sanitation improved. This change also coincided with the disappearance of filariasis carried by *Cx. fatigans*. However, the major pest mosquito at the time was the 'migratory black swamp mosquito, *Aedes vigilax* (Skuse).'

As mentioned above, Dr Elizabeth (Pat) Marks played a part in much of this early mosquito management. She graduated from the University of Queensland with a B.Sc. in 1938, with Second Class Honours in Zoology in 1939 and an M.Sc. in 1940. For her Honours, she specialised in parasitology and was supervised by the former Brisbane City Council Entomologist Hamlyn-Harris, who had become a lecturer in Zoology at the University. He took her collecting mosquitoes in Brisbane and this led to her first scientific publication in 1940, a description of the larva of *Anopheles atratipes* Skuse. Following the malaria epidemic in Cairns in 1942, the Queensland Government established a Mosquito Control Committee (MCC), with the Director of Health as Chairman and F.A. Perkins as Secretary. On 1 April 1943, Pat Marks became the MCC's Graduate Research Assistant, based at

Figs 3-4. (3) 'Demonstration of Modern Pest Control Equipment used by Department of Health, Brisbane City Council' at the City Hall during National Health Week in 1960. Mr J.D. Mabbett is on the steps. (4) The Brisbane City Council Mosquito Control Bike Team, 1980s.

the UQ Department of Entomology and funded by the State Health Department. Apart from her time at Cambridge from 1949-1951, Pat was to occupy this position (with various changes of title) until the MCC was dissolved by the government on 30 June 1973. During that time, she had regular interaction with the Brisbane City Council mosquito control managers, including J.D. (Doug) Mabbett, Chief Health Officer of Brisbane City Council up until 1974.

In 1964, the Brisbane City Council mosquito control group had a permanent staff of 50 and was spending £80,000 annually on control of *Cx. fatigans* in man-made polluted sites. An aerial survey had been conducted from the Mooloolah River to the Tweed River to identify potential saltmarsh breeding sites. For saltmarsh mosquitoes, Mabbett was advocating a combination of land reclamation and an overarching Moreton Bay Regional Control Mosquito Abatement District, for all Local Authorities and the State Government to operate on a joint basis. This initiative was pursued vigorously by a range of pre-eminent mosquito workers, including Pat Marks, Harry Standfast at Queensland Institute of Medical Research (QIMR), Professor Douglas Kettle at the University of Queensland and a number of local government bodies. However, the State government of the day rejected the proposal out of hand. Keith Ferguson of the Gold Coast City Council, tiring of government inaction, established the Contiguous Local Authorities Group (CLAG) in 1968. This group included Gold Coast, Logan, Redland and Albert cities and shires in Queensland, and Tweed shire in New South Wales. CLAG is still functioning and was the forerunner to other successful groups in southeast Queensland that are operating today.

One interesting exercise associated with *Ae. vigilax*, on 6 March 1964, was a fogging exercise around Bulwer Island on the north bank of the Brisbane River at Pinkenba. On that afternoon, Her Majesty Queen Elizabeth II was scheduled to unveil a Memorial Cairn at an oil refinery to mark the discovery of oil in Queensland. The cairn and the Royal pavilion erected for the occasion were within 30 metres of mangroves where prolific numbers of *Ae. vigilax* were resting. The workmen erecting the pavilion had complained of constant attack by both mosquitoes and march flies (Tabanidae). On the day of the function, commencing early in the morning, both vehicle-mounted and hand-held fogging equipment were used to apply 'knockdown and residual formulations' around and through the adjacent mangroves. The last of these applications, in the two hours before the ceremony, also included the repellent diethyl toluamide (DEET). All of this produced 'highly favourable results' and 'the function was held without insect nuisance.' Mabbett published a note on this operation in the American journal *Mosquito News* (Mabbett 1964). The Editor commented that 'There are several points and expressions in this article that may not be entirely clear to readers in other parts of the world, but it is so seldom that we hear from Australia, and the operations described are so interesting, with many useful hints, that it seemed worthwhile to print the account more or less as received.'

The beginning of aerial application techniques

Mabbett was opposed 'in principle' to aerial control of mosquitoes because of its 'hit and miss' nature and potential non-target impacts. However, in 1970, the Council of the day went ahead with a trial of an aerial application of Dibrom, an organophosphate insecticide, aimed at adult *Ae. vigilax* resting in mangroves in the Cribb Island area. A number of scientists, including Harry Standfast, Pat Marks and Geoff Monteith, had spoken out against the trial in its planning stages, labelling it as haphazard. On 17 January, the trial went ahead and the resultant fish kill was featured in the Sunday Mail the following day, with entomologist Geoff Monteith pictured holding a handful of small, dead fish.

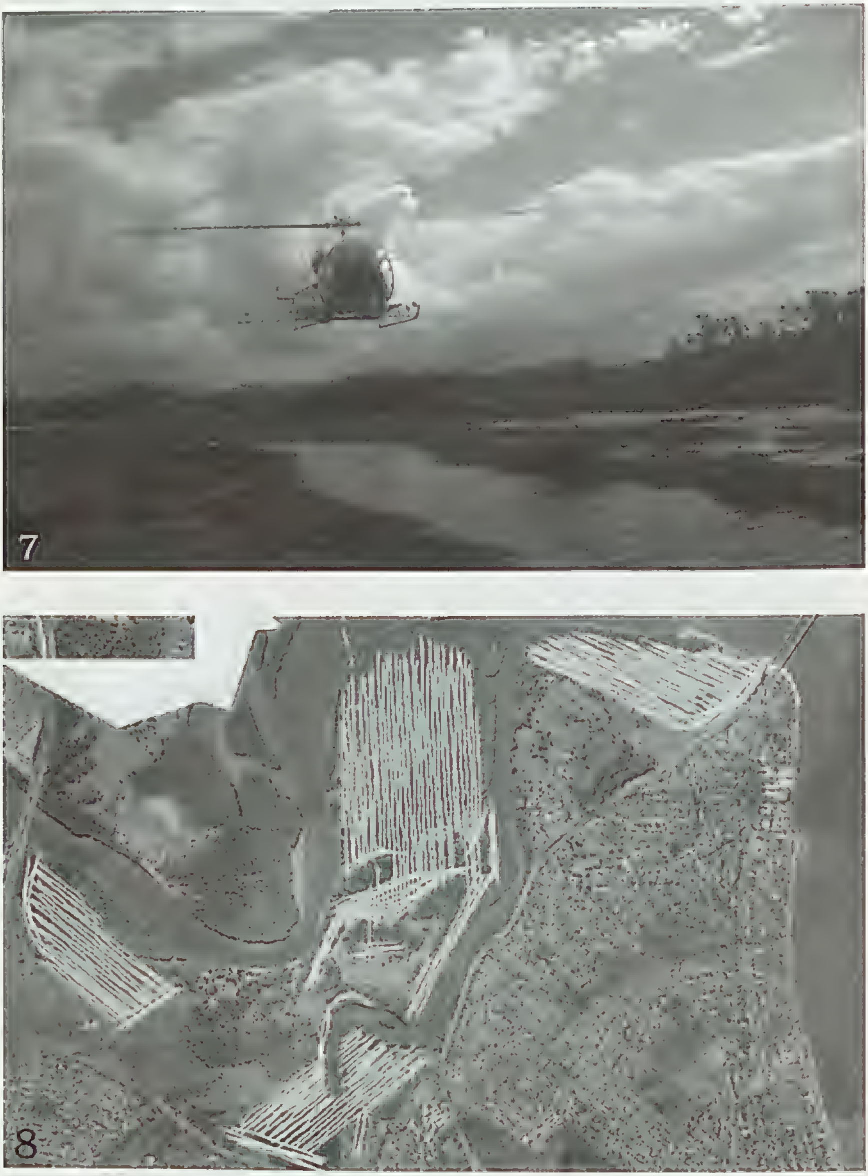
However, efforts to establish aerial control of saltmarsh mosquitoes continued, with the target being larvae rather than adult mosquitoes. This was pioneered in the early 1970s on the Gold Coast by Brian Kay of QIMR, Keith Ferguson of Gold Coast City Council and Dick Morgan of Cyanamid. The product used was a sand grain organophosphate formulation called Abate, a larvicide applied into saltmarsh pools by biplanes. By 1976, an aerial program was operating in Brisbane. Abate was the mainstay of the aerial program until the early 1990s. A liquid formulation was also used by ground staff to target mosquito larvae in both freshwater and saltmarsh pools. Motorcycles with sidecars were a regular feature of the program throughout the 1970s and 1980s (Fig. 4), with the last operator (and sidecar bike) retiring in 1997.

In the early to mid-1990s, laboratory studies using Abate determined that it was potentially harmful to juvenile crustaceans. Bench-top susceptibility tests also revealed that *Ae. vigilax* was developing resistance to this product. It was quite fortuitous that, at this time, two alternative products became available. These were the bacterial protein Bti and the growth regulator S-methoprene. Both products have excellent selectivity for mosquito larvae and are very safe for invertebrate and vertebrate non-target animals.

Bti is produced in a fermentation process by the naturally occurring soil bacteria *Bacillus thuringiensis* var. *israelensis* de Barjac. The active ingredient is a crystalline protein of approximately 10 microns in length that must be eaten by mosquito larvae to have its effect. In the alkaline pH of the larval gut, the crystal breaks down and releases proteins that disrupt the cells of the gut wall and cause the death of the larva, usually within 24 hours. Bti is available in liquid, powder and granular formulations.

S-methoprene growth regulator interferes with the moulting process that occurs between larval stages and between the final larval stage and the pupa.

Figs 5-6. (5) Using a remote-rewind hose unit to treat freshwater mosquito breeding with Bti. (6) A quad bike spraying Bti on saltmarsh mosquito breeding pools in Tinchi Tamba Wetlands.



Figs 7-8. (7) A Bell 47 helicopter applying Bti to saltmarsh pools in Tinchi Tamba Wetlands. (8) The lines on this aerial photograph of Tinchi Tamba Wetlands show the flight path downloaded from the helicopter's GPS unit after an application of S-methoprene on 28 February 2006.

S-methoprene is available as a liquid, in a sand base, and in slow-release charcoal matrix pellets and briquettes.

These products have become the mainstays of mosquito management in Brisbane City Council since 1994. They are used for aerial application from helicopters in saltmarsh areas, and by ground-based staff from four-wheel drive utilities and quad bikes (Figs 5, 6). The capacity to carry out adult mosquito control using fogging or ultra-low-volume misting is maintained, but is rarely used.

Currently, for mosquito management in Brisbane City Council, there are approximately 18 field staff and an annual budget of approximately $3.2 million. The aerial program each year plans to cover 25,000 hectares of saltmarsh in a season from August to May, usually in approximately 20 separate treatments. However, both the total area and the timing can vary with seasonal conditions. Differential Global Positioning Systems are now used routinely in the aerial program, and spray flight paths are overlayed on aerial photographs for every treatment (Figs 7, 8). DGPS is also being used more frequently in ground-based management. For the latter, Brisbane City is divided into nine different sections and a total of approximately 3,000 known and potential mosquito breeding sites on public land are listed on separate databases for each of those sections. The databases include sites such as roadside drains, parks and reserves, and information on the tide heights and rainfall triggers that can initiate mosquito breeding at those sites. The target is to check and treat them in a logical order at intervals short enough to prevent mosquitoes from completing their life cycle.

Brisbane City Council, along with other local government bodies in southeast Queensland, other Councils elsewhere in Queensland and interstate, one industry member and Queensland Health, is a member of the Mosquito and Arbovirus Research Committee Inc. (MARC). Members of MARC contribute funds to a research program at QIMR that studies aspects of mosquito biology and disease transmission, and environmentally sound mosquito control. This group commenced in 1989 with the aim of providing a solid scientific base for mosquito management. It was also a recognition that mosquitoes move freely across local government boundaries. MARC supports a full-time scientist and a number of postgraduate and postdoctoral students based mainly in the mosquito control laboratories at QIMR.

Looking to the future

There will be further challenges in the future. In southeast Queensland, there are significant pressures on development and infrastructure in coastal areas, due to the steady influx of new residents from southern States. Many of these will move into the 'pest range' of saltmarsh mosquitoes in their desire to live adjacent to the coast. And many of the new real estate developments are incorporating what is known as 'Water Sensitive Urban Design' for management of storm water run-off. These features are initially designed to be free of mosquito breeding, but based on experience elsewhere, there are likely to be significant issues with maintenance of these drains in the future. Also, the recent recognition of water as a finite resource means a resurgence in the use of water tanks and various other containers to store water. While modern plastic water tanks certainly have better mosquito-proofing than the old corrugated iron variety, there may be issues with their maintenance in the future that will need to be monitored.

Modern mosquito management has naturally become far more sophisticated and has excellent products and equipment available. And there is now a much clearer recognition that mosquito management programs are carried out in environmentally sensitive and important habitats that require significant duty of care. However, the challenges of knowing the biology and distribution of pest species, and of dealing with them in a variety of seasonal conditions, are still very similar to those faced in earlier times. The one constant in mosquito management is that the target insects are so brilliantly adapted to taking advantage of any ecological niche they find in nature. Skills and experience of mosquito management operators are an essential ingredient of keeping these pests under control. They will be necessary along with ongoing scientific studies to keep mosquito pests and mosquito-borne disease at bay into the future.

Regardless of any current and future studies, all those working in mosquito management will continue to refer to the legacy left by Pat Marks. There will be frequent use of identification keys that she prepared, and regular referral to her publications on the taxonomic descriptions and biology of a vast range of Australian mosquitoes. The recollections given and the broad spread of the presentations in this Symposium have been a fitting commemoration of a remarkable scientific career.

Acknowledgements
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